By H. Ward Silver, NØAX

Amplifier Care and Maintenance

With few moving parts, your amplifier can be easy to overlook. Here are some ideas for taking care of amplifiers.

Amplifiers come in all shapes and sizes, large and small, light or heavy, tube or solid-state, VHF or HF. Regardless, they all need a little TLC from time to time. They can cost as much as top-of-the-line radios, so it's important that they get a little maintenance on a regular basis.

While this article focuses on amplifiers that use vacuum tubes, many of the ideas presented here can and should be applied to any amateur amplifier—HF or VHF/UHF. Solid-state amplifiers operate at lower voltages and generally have fewer points of failure, but they still need occasional maintenance.

Safety First

It is important to review good safety practices.[1] Tube amplifiers use power supply voltages well in excess of 1 kV and the RF output at full throttle can be hundreds of volts, as well. Almost every voltage in an amplifier can be lethal! Take care of yourself and use caution!

- *Power Control*—Know and control the state of both ac line voltage and dc power supplies. Physically disconnect line cords and other power cables when you are not working on live equipment. Use a lockout on circuit breakers. Double-check visually and with a meter to be absolutely sure power has been removed.
- *Interlocks*—Unless specifically instructed by the manufacturer's procedures to do so, never bypass or "rig" an interlock. This is rarely required except in troubleshooting and should only be done when absolutely necessary. Interlocks are there to protect you.
- *The One-Hand Rule*—Keep one hand in your pocket while making any measurements on live equipment. The hand in your pocket won't give current a chance to flow through you. It's also a good idea to wear shoes with insulating soles and work on dry surfaces. Current can be lethal even at milliampere levels—don't tempt the laws of physics.
- *Patience*—Repairing an amplifier isn't a race. Take your time. Don't work on equipment when you're tired or frustrated. Wait several minutes after turning the amplifier off to open the cabinet—capacitors can take several minutes to discharge through their bleeder resistors.
- *A Chicken Stick*—Make this simple safety accessory shown in Figure 1 and use it whenever you work on equipment in which hazardous voltages have been present. The ground wire should be heavy duty (12 gauge minimum) due to the high peak currents (hundreds of amperes) present when discharging a capacitor or tripping a circuit breaker. When equipment is opened, touch the tip of the stick to *every* exposed component and connection that you might come in contact with. Assume nothing—accidental shorts and component failures can put voltage in places it shouldn't be.
- *The Buddy System and CPR*—It's always a good idea to use the buddy system when working around any equipment that has the potential for causing serious injury. The buddy needn't be a ham, just anyone who can be nearby in case of trouble. Your buddy should know how to remove power and administer basic first aid. Since hams work around electrical equipment frequently, it would be a good idea to have your buddy or someone in the household know CPR, as well.[2]

Cleanliness

The first rule of taking good care of an amplifier is cleanliness. I realize that 90 percent of ham shacks have just failed the first rule. Amplifiers need not be kept sparkling new, but their worst enemy is heat. Excess heat accelerates component aging and stresses those expensive tubes and transformers. There are two areas to keep clean—the inside and the outside.

Outside the amplifier, you need to prevent dust and obstructions from blocking the paths by which heat is removed. This means keeping all ventilation holes free of the ever-present dust bunnies, pet hair

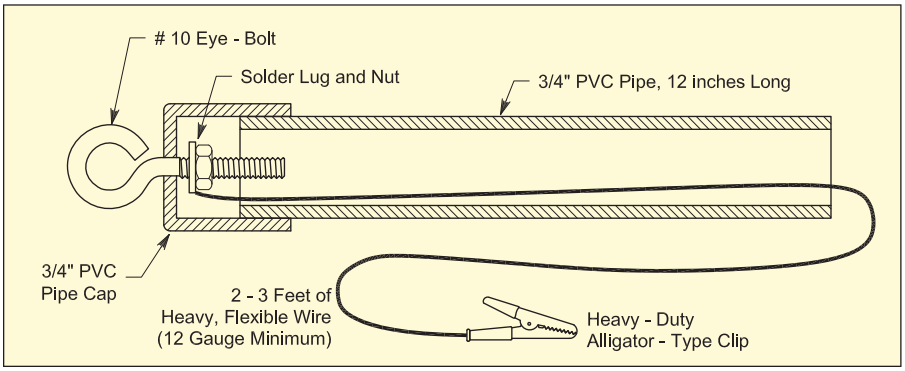

Figure 1—The "chicken stick" is a great way to ensure that everything inside the amplifier that should be discharged actually is. It can be a life saver.

[1]Notes appear on page 37.

and insects. Fan intakes are particularly susceptible to inhaling all sorts of "goop." Get out the vacuum cleaner and clean not only the amplifier, but the surrounding areas. Don't even think about letting liquids anywhere near the amplifier. One spilled cup of coffee can cause hundreds of dollars of damage.

Keep papers or magazines off the amplifier—even if the cover is solid metal. Paper acts as an insulator and keeps heat from being radiated through the cover. Amplifier heat sinks must have free air circulation to be effective. There should be at least a couple of inches of free space surrounding an amplifier on its sides and top. If the manufacturer recommends a certain clearance, mounting orientation or air flow, follow those recommendations.

Just as the outside needs to be kept clean, so does the inside. High voltage (HV) circuits attract dust like crazy. The dust slows heat dissipation and will eventually build up to the point where it arcs or carbonizes. Our friend the vacuum cleaner should make another appearance to remove any dust or dirt. If you find insects (or worse) inside the amp, try to determine how they got in and plug that hole. Window screening works fine to allow airflow while keeping out visitors. While you're cleaning the inside, this is a great time to perform a visual inspection as described in the next section.

Vacuuming works best with an attachment commonly known as a "crevice cleaner." Figure 2 shows a crevice cleaning attachment being used with a small paintbrush to dislodge and remove dust. Don't use the vacuum cleaner brush attachment; they're designed for floors, not electronics. Some vacuums also have a blower mechanism, but these rarely have enough punch to clean as thoroughly as a brush. Besides, that dust you blow all over is going to wind up in some other equipment, so it's best to take it out of circulation, so to speak. The brush will root dust out of tight places and off components without damaging them or pulling on connecting wires.

If you can't get a brush or attachment close enough, a spray can of compressed air will usually dislodge dust and dirt. If you use a rag or towel to wipe down panels or large components, be sure not to leave threads or lint behind. Never use a solvent or spray cleaner to wash down components unless the manufacturer advises doing so—you might leave behind a residue or damage the component.

Visual Inspection

Once the amplifier has been cleaned, it's time for a visual inspection. Remove any internal covers or access panels and...*stop*! Get out the chicken stick, clip its ground lead securely to the chassis and touch every exposed connection. Now, using a strong light and possibly a magnifier, look over the components and connections. Amplifiers have far fewer components than transceivers do, so it's quite feasible to look at every component and insulator. Look for cracks, signs of arcing, carbon traces (thin black lines), discoloration, loose connections, melting of plastic, and anything else that doesn't "look right." This is a great time to be sure that mounting and grounding screws are tight. While you're in there, does anything smell burnt? The nose can quickly detect the odors of toasted transformer, cooked capacitor or roasted resistor. Learn the smells of healthy and not-so-healthy components.

Make a note of what you find, repair, or replace—even if it's absolutely nothing. If you don't keep a shack notebook, start one. A simple spiral notebook with notes about maintenance, wiring, color coding, antenna behavior and so forth can be a big time-saver.

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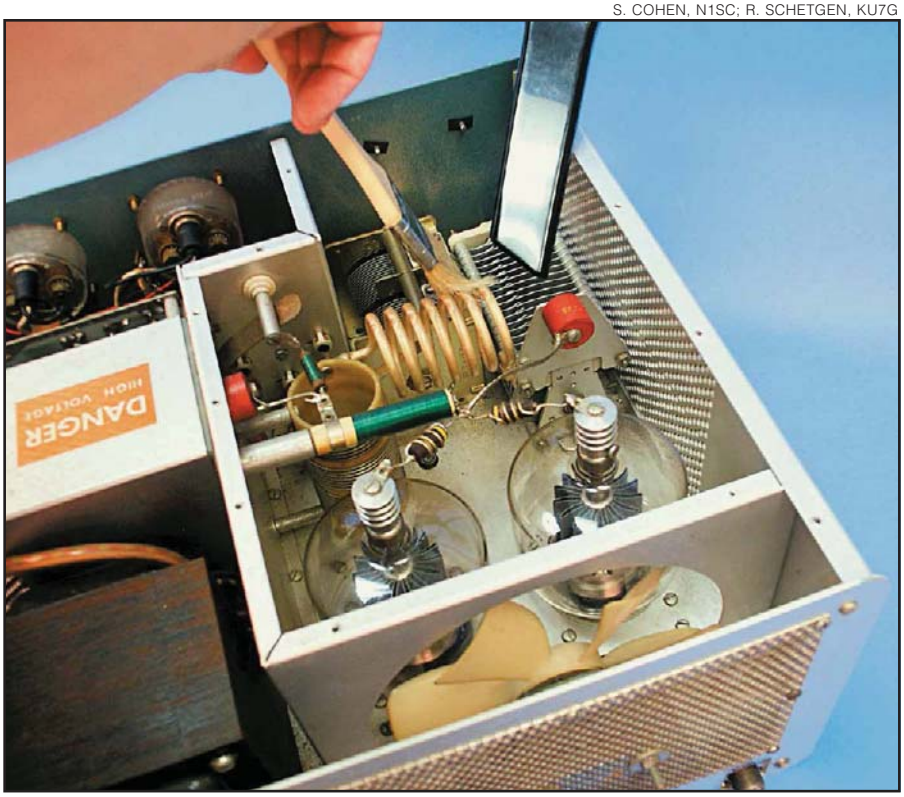

Figure 2—A small paintbrush and a vacuum cleaner crevice attachment make dust removal easy.

Electrical Components

An amplifier contains many heavy-duty HV and RF components. These can be expensive and hard to replace, so it's important that you take good care of them. Let's start with the power supply.

There are three basic parts to amplifier power supplies—the ac transformer and line devices, the rectifier/filter and the metering/regulation circuitry. Transformers need little maintenance except to be kept cool and be mounted securely. Line components such as switches, circuit breakers and fuses, if mechanically sound and adequately rated, are usually electrically okay, as well.

Rectifiers and the capacitors that filter the HV dc require occasional cleaning. Look for discoloration around components mounted on a printed circuit board (PCB) and make sure that all wire connections are secure. HV capacitors are generally electrolytic or oil and should show no signs of leakage, swelling or outgassing around terminals.

Located at the output of the filter, components that perform metering and regulation of voltage and current can be affected by heat or heavy dust. If there has been a failure of some other component in the amplifier—such as a tube—these circuits can be stressed severely. Resistors may survive substantial temporary overloads, but may show signs of overload, such as discoloration or swelling.

Amplifiers contain two types of relays—control and RF. Control relays switch ac and dc voltages and do not handle input or output RF energy. The usual problem encountered with control relays is oxidation or pitting of their con-

tacts. A burnishing tool can be used to clean relay contacts. In a pinch a strip of ordinary paper can be pulled between contacts gently held closed. [Avoid the temptation to over-clean silver-plated relay and switch contacts, as the author points out later. It is easy to remove contact plating with excessive polishing and while silver-plated relay and switch contacts may appear to be dark in color, oxidized silver (black) is still a good conductor. Once the silver's gone, it's gone; contact erosion will then be pervasive.—*Ed.*] If visual inspection shows heavy pitting or discoloration or resistance measurements show the relay to have intermittent contact quality, it is best replaced.

RF relays are used to perform transmit-receive (TR) switching and routing of RF signals through or around the amplifier circuitry. Amplifiers designed for full break-in operation will usually use a high-speed vacuum TR relay. Vacuum relays are sealed and cannot be cleaned or maintained. When you replace RF relays, use a direct replacement part or one rated for RF service with the same characteristics as the original.

Cables and connectors are subjected to heavy heat and electrical loads in amplifiers. Plastics may become brittle and connections may oxidize. Cables should remain flexible and not be crimped or pinched under clamps or tie-downs. It's a good idea to gently wiggle cables while watching the connections at each end for looseness or bending. Connectors can be unplugged and reseated once or twice to clear oxide on contact surfaces. Carefully inspect any connector that seems loose. Be especially careful with connectors and cables in amplifiers that have RF decks that are in separate enclosures from those of their power supplies. Those interconnects are susceptible to both mechanical and electrical stress and you don't want an energized HV cable loose on the operating desk. Check both the soldered electrical integrity and the mechanical stability of those cables and make sure they are tightly fastened.

As with relays, switches found in amplifiers are either control function orientated or RF routers. Adequately rated control switches, if mechanically sound, are usually okay. Bandswitches are the most common RF switch—usually a rotary phenolic or ceramic type. A close visual inspection should show no pitting or oxidation on the wiper (the part of the switch that rotates between contacts) or the individual contacts. Arcing or overheating will quickly destroy rotary switches. Figure 3 is a photo of a heavy-duty band switch that has suffered severe damage from arcing. Slight oxidation is acceptable on silver-plated switches. Phosphor-bronze contacts can sometimes be cleaned with a light scrub from a pink pencil eraser, but plating can be easily removed, so use caution with this method and be sure to remove any eraser crumbs. Rotary switch contacts cannot be replaced easily although individual wafer sections may be replaced if an exact matching part can be obtained.

Amplifiers use all types of capacitors and resistors. When replacing them, be sure to use a part rated for the use to which it will be put. Voltage and power-handling ratings are particularly important, especially of those handling high RF currents. An RF tank capacitor replacement should be checked carefully for adequate RF voltage and current ratings, not just dc. HV resistors are generally long and thin to prevent arcing across their surfaces. Even if a smaller (and cheaper) resistor has an equivalent power rating, resist the temptation to substitute it. In a pinch, a series string of resistors of the appropriate combined value can be used to replace one HV unit. Don't use carbon resistors for metering circuits, use metal or carbon film types. The carbon composition types are too unstable.

If you are repairing or maintaining an old amplifier and manufacturer-specific parts are no longer available, the ham community has many sources for RF and HV components. Fair Radio Sales and Surplus Sales of Nebraska are familiar names.[3] Hamfests and Web sites such as **www.eham.net** or **www.k1dwu.net/hamtrader** often have amplifier components for sale. You might consider buying another amplifier of the same type in non-working condition for parts use.

Tubes

The single most expensive component in an amplifier is usually the vacuum tube that performs the amplification. Good maintenance of tubes starts with proper operation of the amplifier. Follow the manufacturer's instructions for input drive levels, duty cycles, tuning and output power level. Frequently check all metered voltages and current to be sure that the tubes are being operated properly and giving you maximum lifetime. Penta Labs has an excellent Web page on maintaining power tubes.[4]

The internal mechanical structures of tubes generally do not deal well with mechanical shock and vibration, so be gentle. The manufacturer may also specify how the amplifier is to be mounted, so read the operating manual.

Tubes generate a lot of heat, so it's important that whatever cooling mechanism employed is kept at peak efficiency. Airways should be clean, including between the fins on metal tubes. All seals and chimneys should fit securely and be kept clean. Wipe the envelope of glass tubes clean after handling them—fingerprints should be removed to prevent baking them into the surface.

On metal tubes that use finger-stock contacts, be sure the contacts are clean and make good contact all the way around the tube. Partial contact or dirty finger stock can cause asymmetric current and heating inside the tube, resulting in warp-

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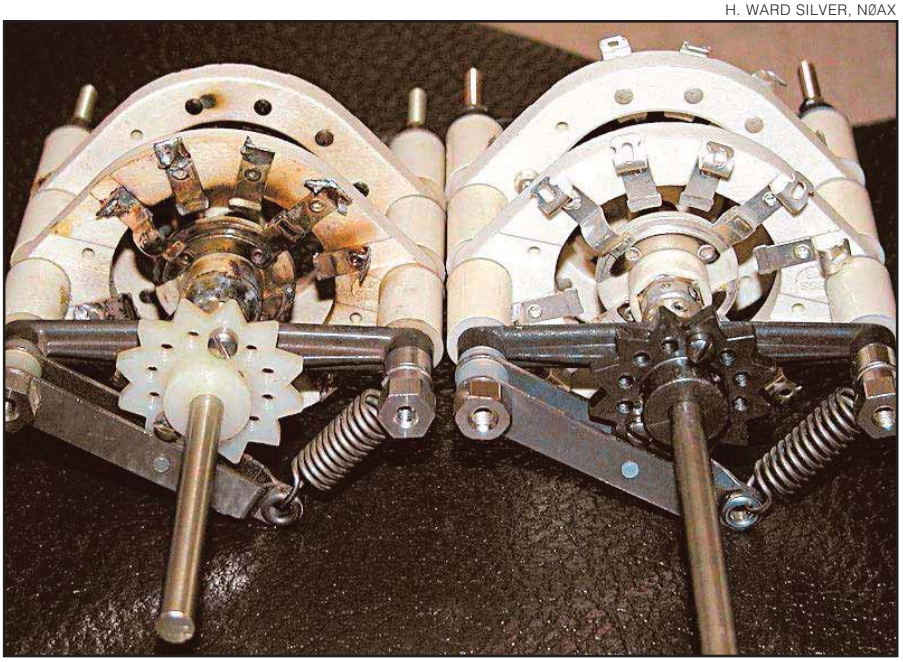

Figure 3—The band switch section on the left clearly shows the signs of destructive arcing.

ing of internal grids and possibly causing harmonics or parasitics.

Plate cap connections and VHF parasitic suppressors should be secure and show no signs of heating. Overheated parasitic suppressors may indicate that the neutralization circuit is not adjusted properly. Inspect socket contacts and the tube pins to be sure all connections are secure, particularly high-current filament connections. Removing and inserting the tubes once or twice will clean the socket contacts.

Adjustments to the neutralizing network, which suppresses VHF oscillations by negative feedback from the plate to grid circuit, are rarely required except when you are replacing a tube or after you do major rewiring or repair of the RF components. The manufacturer will provide instructions on making these adjustments. If symptoms of VHF oscillations occur without changing a tube, then perhaps the tube characteristics or associated components have changed. Parasitic oscillations in high-power amplifiers can be strong enough to cause arcing damage. Perform a visual inspection prior to readjusting the neutralizing circuit.

Metering circuits rarely fail, but they play a key part in maintenance. By keeping a record of "normal" voltages and currents, you will have a valuable set of clues when things go wrong. This is perfect information for the shack notebook. Record tuning settings, drive levels, and tube voltages and currents on each band and with every antenna. When things change, you can refer back to the notebook instead of relying on memory.

Mechanical

While the amplifier is primarily an electronic beast, it has a significant number of mechanical parts that affect its well-being. Thermal cycling and heat-related stresses can result in mechanical connections loosening over time or material failures.

Switch shafts, shaft couplings and panel bearings all need to be checked for tightness and proper alignment. All mounting hardware needs to be tight, particularly if it supplies a grounding path. Examine all panel-mounted components, particularly RF connectors, and be sure they're attached securely. BNC and UHF connectors that are mounted with a single nut in a round panel hole are notorious for loosening with repeated connect/disconnections.

Rubber and plastic parts are particularly stressed by heat. If there are any belts, gears or pulleys, make sure they're clean and that dust and lint are kept out of their lubricant. Loose or slipping belts should be replaced. Check O-rings, grommets and sleeves to be sure they are not brittle or cracked. If insulation sleeves or sheets are used, check to be sure they are covering what they're supposed to. Never discard them or replace them with improperly sized or rated materials.

Enclosures and internal shields should all be fastened securely with every required screw in place. Watch out for loosely overlapping metal covers. If a sheet metal screw has stripped out, either drill a new hole or replace the screw with a larger size, taking care to maintain adequate clearance around and behind the new screw. Tip the amplifier from side to side while listening for loose hardware or metal fragments, which should all be retrieved.

A great time to clean the front and back panels and get gummy finger deposits off before they cause permanent finish damage is during maintenance. If the amplifier is missing a foot on the cabinet or an internal shock mount, replace it. A clean unit with a complete cabinet will have a significantly higher resale value than a dirty, grubby one, so it's in your interest to keep the equipment looking its best.

Shipping

When you are traveling with an amplifier or shipping it, some care in packing will prevent needless damage. Improper packing can also result in difficulty in collecting on an insurance claim, should damage occur. The original shipping cartons are a good method of protecting the amplifier for storage and sale, but they were not made to hold up to frequent shipping. If you travel frequently, it is best to get a sturdy shipping case made for electronic equipment.[5]

Some amplifiers require the power transformer to be removed before shipping. Check your owner's manual or contact the manufacturer to find out. Failure to remove it before shipping can cause major structural damage to the amplifier's chassis and case.

Tubes should also be removed from their sockets for shipment. It may not be necessary to ship them separately if they can be packed in the amplifier's enclosure with adequate plastic foam packing material. If the manufacturer of the tube or amplifier recommends separate shipment, however, do it!

Cleaning and Maintenance Plan

This discussion should have given you plenty to think about. It's easy to defer maintenance, but as with a vehicle, performance and lifetime are improved if a regular program is put into place. For amateur use, there is little need for maintenance more frequently than once per year. If there is a period of the year in which you are most active, put a note on the calendar about six weeks in advance to "open the hood," giving you time to obtain and replace any components.

Consider the maintenance requirements of your amplifier and what its manufacturer recommends. Sit down with your amplifier's manuals and make up a checklist of what major steps and tools are required. When maintenance time rolls around, you'll be prepared and be able to perform the job in the most efficient manner.

Troubleshooting

A benefit of regular maintenance will be familiarity with your amplifier should you ever need to repair it. Knowing what it looks (and smells) like inside will give you a head start on effecting a quick repair.

The following discussion is intended to illustrate the general flow of a troubleshooting effort, not be a step-by-step guide. Figure 4 shows a moderately-high-level troubleshooting flow chart. Before starting on your own amplifier, review the amplifier manual's "Theory of Operation" section and familiarize yourself with the schematic. If there is a troubleshooting procedure in the manual, follow it, of course.

You might be surprised how many "amplifier is dead" problems turn out to be simply a lack of ac power. Before even opening the cabinet of an unresponsive amplifier, be sure that ac is really present at the wall socket and that the fuse or circuit breaker is really closed. Assuming that ac power is present, trace through any internal fuses, interlocks and relays all the way through to the transformer primary terminals.

Hard failures in a high voltage power supply are rarely subtle, so it's usually clear if there is a problem and what components are involved. When you repair a power supply, take the opportunity to check all related components. If all defective components are not replaced, the failures may be repeated when the circuit is re-energized.

Rectifiers may fail open or shorted—test them using a DVM diode checker. An open rectifier will result in a drop in the HV output of 50 percent or more but will probably not overheat or destroy itself. A shorted rectifier failure is usually more dramatic and may cause additional rectifiers or filter capacitors to fail. If one rectifier in a string has failed, it may be a good idea to replace the entire string as the remaining rectifiers have been subjected to a higher-than-normal voltage.

High voltage filter capacitors usually fail shorted, although they will occasionally lose capacitance and show a rise in ESR (equivalent series resistance). Check the rectifiers and any metering compo-

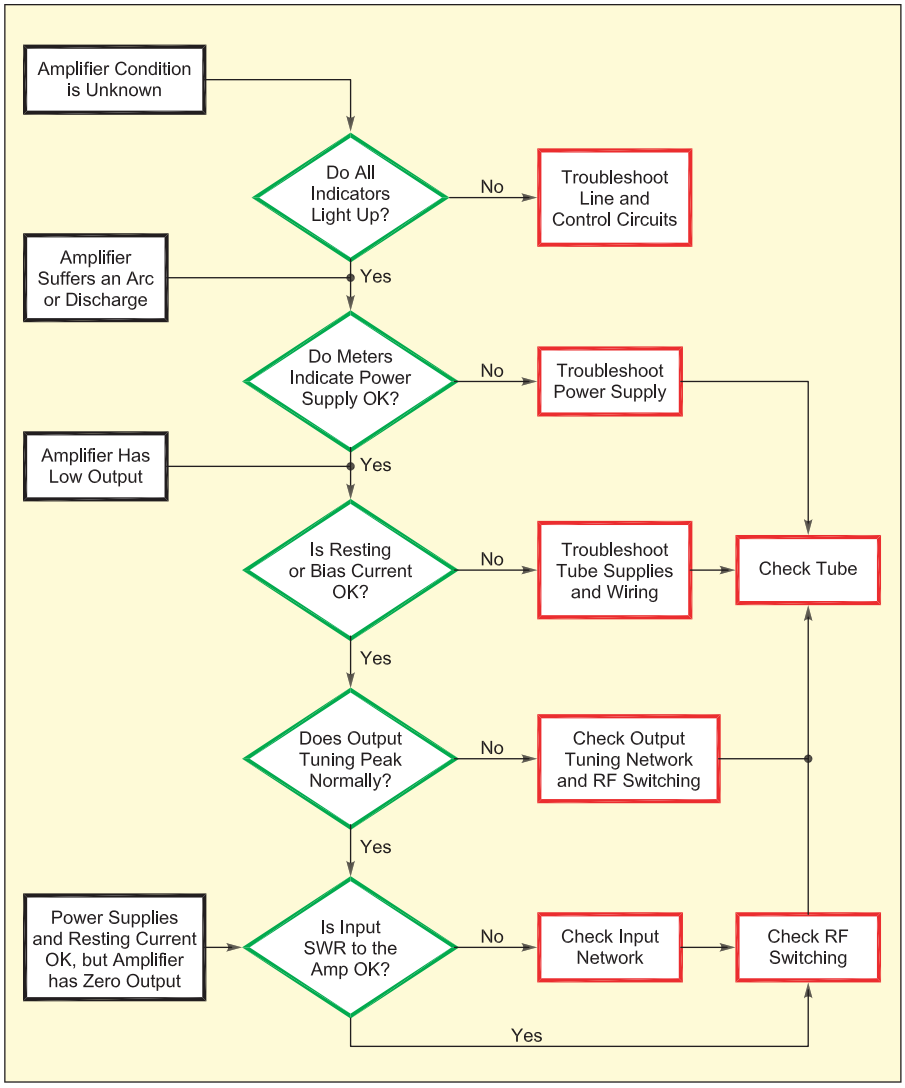

Figure 4—This moderate-level flow chart is a good way to identify amplifier problems quickly in lieu of a misplaced or nonexistent manufacturer's troubleshooting procedure.

nents—they may have been damaged by the current surge caused by a shorted filter. Power transformer failures usually manifest themselves by insulation failures with consequent arcing of the windings. Either can result in the unmistakable aroma of overheated transformer. A failed transformer is generally not repairable.

Along with the HV plate supply, tetrode screen supplies occasionally fail, too. The usual cause is the regulation circuit that drops the voltage from the plate level. Operating without a screen supply can be damaging to a tube, so be sure to check the tube carefully after repairs.

If the power supply checks out okay and the tube's filaments are lit, check the resting or bias current. If it is excessive or very low, check all bias voltages and dc current paths to the tube, such as the plate choke, screen supply (for tetrodes) and grid or cathode circuits.

Having exhausted power supply and dc problems, you will then turn to the RF components or "RF deck." There is a natural tendency to forge ahead and swap in a known-good tube or tubes. Don't! Tubes are expensive and if the problem is elsewhere, you may damage the spares. Wait to swap tubes until you are sure that the tube is likely to be defective.

Check the input SWR to the amplifier. If it has changed (you did write down the normal SWR and drive levels, didn't you?) then you likely have a problem in the input circuitry or one or more tubes have failed. Perform a visual check of the input circuitry and the band switch, followed by an ohmmeter check of all input components.

If input SWR is normal and applying drive does not result in any change in plate current, you may have a defective tube, tube socket, or connection between the input circuits and the tube. Check the TR control circuits and relay. If plate current changes, but not as much as normal, try adjusting the output tuning circuitry. If this has little or no effect, the tube may be defective or a connection between the tube and output circuitry may have opened. If retuning has an effect, but at different settings than usual, the tube may be defective or there may be a problem in the tuning circuitry. A visual inspection and an ohmmeter check are in order.

The key to finding the trouble with your amplifier is to be careful and methodical, and to avoid jumping to false conclusions or making random tests. The manufacturer's customer service department will likely be helpful if you are considerate and have taken careful notes detailing the trouble symptoms and any differences from normal operation. There may be helpful guidelines on the manufacturer's Web pages or from other Internet resources. Sometimes there is more than one problem—they work together to act like one very strange puzzle. Just remember that most problems are very simple and can be isolated by careful, step-by-step tests.

Summary

Amplifiers have been part of ham radio for many years. They are simple, reliable pieces of equipment that respond well to basic care and common sense. Take the time to know your amp—inside and out. If you take care of it, it will reward you with reliable service and maximum tube lifetime.

Notes

[1]Chapter 9 of the current *ARRL Handbook for Radio Communications* is an excellent source of safety information. Available from your local dealer or the ARRL Bookstore. Order no. 1921 (softcover), no. 1948 (hardcover). Telephone toll-free in the US 888-277-5289, or 860-594-0355, fax 860-594-0303; **www.arrl.org/shop/**; **pubsales@arrl.org**.

[2]Instructions for CPR can be found at: **about-the-web.com/spiritworks/web/Kaiser/html/adult.htm**.

[3]Two sources of HV and RF parts include Surplus Sales of Nebraska (**www.surplussales.com**) and Fair Radio Sales (**www.fairradio.com**). Others can be found at the ARRL Technical Information Service database (**www.arrl.org/tis/tisfind.html**).

[4]Penta Labs, "Tube Maintenance & Education" (**www.pentalaboratories.com/maintenance.asp**).

[5]Pelican (**www.pelican-shipping-cases.com**) and Anvil (**www.anvilsite.com**) make excellent shipping cases suitable for carrying amplifiers and radio equipment.

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